

TABLE OF CONTENTS

CHAPTER	TITLE	PAGES
	TABLE OF CONTENTS	vii
	LIST OF FIGURES	xi
	LIST OF TABLES	xvi
	LIST OF SYMBOLS	xvii
1	INTRODUCTION	1
	1.1 Objective of the Project	2
	1.2 Scopes of the project	3
	1.3 Methodology of the Project	3
	1.4 Thesis Organization	5
2	LITERATURE REVIEW	6
	2.1 Introduction to Necking Study	6
	2.2 Necking in the Tensile Test Formulae of Normalized Axial Stress	8
	2.3 Critical Analysis of Plastic Material Properties	11
	2.4 Influenced of parameter to the equation of Stress and Strain Approximation Formula	18

3	GENERALIZED CONCEPTS OF ELASTIC AND PLASTIC DEFORMATION	20
	3.1 Introduction	20
	3.2 Stress-Strain Relationships	23
	3.2.1 Elastic – Plastic Behaviour	23
	3.3 Material Behaviour	24
	3.3.1 Elastic Perfectly Plastic Model	27
	3.3.2 Elastic-Linear Work-Hardening Model	27
	3.3.3 Elastic-Exponential Hardening Model	28
	3.3.4 Ramberg-Osgood Model	28
	3.4 Yield Criteria	29
	3.4.1 Tresca Yield Criterion	30
	3.4.2 von-Mises Yield Criterion	31
	3.5 Hardening Rule	32
	3.5.1 Isotropic Hardening Rule	34
	3.5.2 Kinematic Hardening Rule	34
4	METHODOLOGY	37
	4.1 Introduction to the Finite Element Analysis	37
	4.2 Finite Element Method	38
	4.3 Finite Element Codes	40
	4.4 Numerical Verification of the Tensile Specimen	41
	4.4.1 Numerical Modeling	42
	4.4.2 Model Description	42
	4.4.3 Meshing the Model	44
	4.4.4 Boundary Condition	47

4.4.5 Loading the Model	48
4.4.6 Result Validation and Error Estimation	49
4.5 Determination of Radius of Curvature	50
4.5.1 Curvature of Plane Curves	50
4.5.2 Local expressions	52
5 RESULTS AND DISCUSSIONS	54
5.1 Results of Meshing Comparison	54
5.2 Finite Element analysis of tensile test	60
5.3 Radius of Curvature at Necking Region	62
5.4 Engineering Analysis on the Stress – Strain Curve	64
5.4.1 Engineering Stress Strain Curve	65
5.4.2 True Stress Strain Curve	67
5.5 Analysis Model for Tensile Test and the Simulation Results	70
5.5.1 Analysis on the Stress Distribution a the Critical Point After necking	72
5.5.2 Results of Eq. Stress and Strain along the Critical Necking Nodes at Last Increment	74
5.5.3 Results Comparison of Distribution of Equivalent Plastic Strain with Approximation Formula.	76
5.5.4 Assessment on the Equivalent Stress of Simulation Results and Approximation Formula	79
5.5.5 Analysis on Flow Curve from Finite Element Simulation and the Approximation Formula	82

6	CONCLUSIONS AND FURTHER WORK	86
	REFERENCES	88

LIST OF FIGURES

FIGURE NO	TITLE	PAGE
1.1	Research methodology flowcharts	4
2.1	Neck geometry of a tensile specimen	10
2.2	Initial and final shape of tensile specimen for linear hardening	12
2.3	Distribution of stress component σ_r , σ_z , σ_θ in the minimum section for the last increment (linear hardening)	13
2.4	Comparison of equivalent stresses obtained from FE analysis and the approximation formulae in the minimum section for the last increment for linear hardening	14
2.5	True and equivalent stress as a function of equivalent plastic strain and optical determination of the actual geometry	16
2.6	Equivalent plastic strain as a function of radial coordinate	17
2.7	Triaxiality as a function of radial coordinate	17
2.8	Equivalent Plastic Strain versus the ratio of initial diameter with final diameter	18
2.9	Equivalent Plastic Stress σ_v/σ versus radius of curvature	19

Figure 3.1	Typical stress versus strain diagram with various stages of deformation	20
3.2	Stress-Strain curves	24
3.3	Idealized stress-strain curves	26
3.4	Yield loci for Tresca and von-Mises criteria in a biaxial stress state	31
3.5	Stress-strain curve for uniaxial loading	33
3.6	Isotropic hardening - same shape, different size	34
3.7	Bauschinger effect for uniaxial loading,	35
3.8	Kinematic hardening - same shape, same size	35
4.1	Integration Points for axisymmetric model	40
4.2	Round Cylinder Model for the Tensile test Analysis	41

4.3	Ideal Plasticity	43
4.4	Linear hardening	43
4.5	Non-linear Hardening	44
4.6	Initial meshing	45
4.7	Element with one hanging nodes and transition elements	45
4.8	Fine mesh of axisymmetric model (240 elements)	46
4.9	Description of mesh num of elements	47
4.10	Mechanical boundary conditions for linear hardening.	48
4.11	Mechanical boundary set-up in the MSC Marc	48
4.12	Setting in MSC Marc FE codes for linear hardening	49
4.13	Circle on a curvature	52
4.14	Graph coordinates of y versus x along the necking curvature.	53
5.1	Physical indicator of the problem	54
5.2	Reaction force versus number of elements for ideal plasticity model	55
5.3	Reaction force versus number of elements for linear hardening model	55
5.4	Reaction force versus number of elements for non linear model	56
5.5	y-displacement versus number of elements for ideal plasticity model	56
5.6	y-isplacement versus number of elements for linear hardening model	57
5.7	y-displacement versus number of elements for non linear model	57
5.8	Undeformed shape and deformed shape of tensile specimen for ideal plasticity	60
5.9	Undeformed shape and deformed shape of tensile specimen for non linear hardening	61

5.9	Undeformed shape and deformed shape of tensile specimen for linear hardening	61
5.10	Engineering Stress Strain curve for ideal plasticity	65
5.11	Engineering Stress Strain curve for linear hardening	66
5.12	Engineering Stress Strain curve for non linear hardening	67
5.13	True stress strain curve of tensile specimen	69
5.14	True and equivalent stress as a function of equivalent plastic strain	71
5.15	Distribution of stress component axial stress, radial stress and circumferential stress in the minimum section for the last increment.	73
5.16	Distribution of equivalent stress and equivalent plastic strain in the minimum section for the last increment (ideal plasticity model).	74
5.17	Distribution of equivalent stress and equivalent plastic strain in the minimum section for the last increment (linear hardening model).	75
5.18	Distribution of equivalent stress and equivalent plastic strain in the minimum section for the last increment (non linear hardening model).	76
5.19	Comparison of equivalent plastic strain obtained from FE simulation and approximation formula at the critical necking region for the last increment (ideal plasticity model)	77
5.20	Comparison of equivalent plastic strain obtained from FE simulation and approximation formula at the critical necking region for the last increment (linear hardening model)	78

5.21	Comparison of equivalent plastic strain obtained from FE simulation and approximation formula at the critical necking region for the last increment (non linear hardening model)	79
5.22	Comparison of equivalent stresses obtained from finite element analysis and approximation formula in the minimum section for the last increment of ideal plasticity model.	80
5.23	Comparison of equivalent stresses obtained from finite element analysis and approximation formula in the minimum section for the last increment of linear hardening model.	81
5.24	Comparison of equivalent stresses obtained from finite element analysis and approximation formula in the minimum section for the last increment of non linear hardening model.	82
5.25	Exact and reconstructed flow curves for ideal plasticity.	83
5.26	Exact and reconstructed flow curves for linear hardening.	83
5.27	Exact and reconstructed flow curves for non linear hardening.	84
5.28	Comparison of error estimation between two approximation formula, Bridgman and Davidenkov-Spiridonova.	84

LIST OF TABLES

TABLE NO	TITLE	PAGE
4.1	Material properties of Specimen	40
4.2	Load applied	49
4.3	Coordinate of x and y along the necking curvature for non linear hardening model (Inc = 600)	53
5.1	Results of Meshing Comparison	59
5.2	Radius of curvature for Ideal Plasticity Model	63
5.3	Radius of curvature for Linear Hardening Model	63
5.4	Radius of curvature for Linear Hardening Model	64

LIST OF SYMBOLS

SYMBOL	DESCRIPTION
ρ	curvature of the longitudinal stress trajectory
a	radius at necking area
R	Radius of curvature
$\bar{\sigma}_z$	Equivalent stress
F	Force
A	Area
d	Diameter
ε_N	natural strain
ε_c	engineering strain
σ	true stress
E	Young's Modulus
$d\varepsilon$	increment of strain
$d\varepsilon_e$	elastic strain increment
$d\varepsilon_p$	plastic strain increment
$d\sigma$	stress increment
E_t	tangent modulus
ν	Poisson's ratio
ε_p	plastic strain
σ_Y	yield stress
k	characteristic constants

N	characteristic constants
σ_{v_M}	von-Mises equivalent stress
σ_{T_r}	Tresca equivalent stress
σ_θ	circumferential stress
σ_r	radial stress
τ_{max}	maximum shear